

A new species of *Ferdina* (Echinodermata: Asteroidea) from the Sultanate of Oman with discussion of the relationships of the genus within the family Ophidiasteridae.

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SYNOPSIS. A new species of ophidiasterid starfish, from shallow water on the coast of Oman, is described in the formerly monotypic genus *Ferdina*. The diagnosis of the genus given by Clark (1967) is amended to accommodate the new species and a discussion and key are provided to distinguish *Ferdina* from related genera.

INTRODUCTION

The shallow-water Asteroid fauna of Oman and Yemen is not well known and ecological and zoogeographic studies by one of us (Campbell & Morrison (1988) and Campbell, in prep.) have added many species to those listed by Clark & Rowe (1971) and Price (1982).

The south coast of Oman, although lying between the latitudes of 19°00'N and 16°40'N has marked variation in temperature and nutrient levels due to seasonal upwelling along the very narrow continental shelf, particularly in the vicinity of Sadh. The coast is affected by the South-West Monsoon for four months of the year (June to September); this brings marked changes in the sea water conditions with temperatures falling from 28°C (pre-monsoon) to 18°C (monsoon) and nutrients rising from 0.4–0.6 micrograms dm⁻³ (pre monsoon surface phosphate) to > 1.0 micrograms dm⁻³ (post monsoon). Surface nitrate over the same period rises from <0.5 micrograms dm⁻³ to >10.00 dm⁻³. The fall in water temperature and the sudden influx of nutrients results in a rapid growth of macroalgae. Campbell & Morrison (1988) give a fuller account of the physical and biological features of the region.

These conditions result in a mixed fauna of tropical and temperate species. The asteroid fauna, however, consists entirely of tropical species or endemic species with tropical affinities.

One of the latter is a new species described herein.

FERDINA Gray

Ferdina Gray, 1840: 282; 1866: 12–13; Perrier, 1875: 183; Fisher, 1919: 370; H. L. Clark, 1921: 58; Livingstone, 1931: 305, A. M. Clark, 1967: 191–193.

TYPE SPECIES. *Ferdina flavescens* Gray, 1840; designated by Fisher, 1919.

DIAGNOSIS. After Clark (1967), amended.

A genus of Ophidiasteridae with the abactinal skeleton consisting of irregularly placed larger plates superimposed on close fitting smaller ones leaving space between for small papular areas with one to five pores in each; an indistinct carinal series of plates may be evident; the limits of the underlying plates are concealed by continuous granulation (granules even sized or markedly larger on the convex plates than between them); superomarginal plates meet inferomarginals at the base and tip of the rays, elsewhere the superomarginals may be separated from the inferomarginals by intermarginal plates which lie between the irregular, or alternating large and small superomarginals and the regular series of inferomarginals; actinal and adambulacral plates concealed by continuous granulation, extending partway up the outer side of the furrow spines: adambulacral plates with a single row of short blunt furrow spines; actinal papulae

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restricted to occasional ones at the lower corner of the inferomarginal plates.

Species included: *Ferdina flavescens* Gray, 1840; *Ferdina sadhensis* sp. nov.

DISCUSSION. The genus *Ferdina* was erected for the species *F. flavescens* and *F. cumingii* Gray, 1840. The two species were more fully described by Perrier (1875) and the description of *F. flavescens* was expanded by de Loriol (1885). Livingstone (1931) restricted the genus *Ferdina* to *F. flavescens* and a new species, *F. heffernani* assigning *F. cumingii* to a new genus, *Neoferdina*, characterised by having some marginal plates bare of granules. A. M. Clark (1967) recognising that *F. heffernani* was unlike *Ferdina* in many respects, re-defined *Ferdina* and erected a new genus *Celerina* of which *F. heffernani* became the type species. Jangoux (1973) re-defined *Neoferdina* including several points omitted by Livingstone, but omitting the important point that the superomarginals are usually more conspicuous than in *Ferdina*. James (1973) described the genus *Paraferdina* for the new species *P. laccadivensis* which differs from *Ferdina* in having fairly large, regular superomarginal plates, and from *Neoferdina* in having all plates completely covered by granules. *P. laccadivensis* is redescribed and a second species of *Paraferdina* described by Marsh & Price (1991). Liao (1982) described the genus *Sinoferdina*, with type species *S. gigantea* from China. This genus differs from *Ferdina* and *Paraferdina* in having some bare marginal plates and from *Neoferdina* in having small, fairly regularly arranged abactinal plates with a distinct carinal series, none of which is bare, and in having smaller less conspicuous superomarginals. *Ferdina* was then left as a monotypic genus to which a second species is now added.

The genera *Ferdina*, *Neoferdina*, *Paraferdina* and *Sinoferdina* are here regarded as forming a natural group based principally on the character of the actinal surface and furrow armature. They are distinguished from all other ophiasterids by having the adambulacral armature in a single series of blunt-ended furrow spines with at least half their length concealed, on the outer side, by a thick, granule-covered integument. The actinal surface is covered by small granules with little, if any, difference in size between those on the plates and between them, however, the latter are usually conspicuous because of their contrasting colour.

Celerina, a monotypic genus separated from *Ferdina* by A. M. Clark (1967), also has a single series of adambulacral spines but these are generally sharply pointed and not at all covered by granulated skin. In *Celerina* the spines on the oral plates, except those at the apex of the jaw, are smaller than the furrow spines, while in the *Ferdina* group they are indistinguishable from the furrow spines. *Celerina* resembles *Fromia monilis* in colour pattern, and arrangement of abactinal and marginal plates and is here regarded as having its closest affinity with *Fromia* despite its lack of actinal papulae and differences in furrow armature.

Ferdina, *Neoferdina*, *Paraferdina* and *Sinoferdina* have broad-based tapering arms with usually little regularity in abactinal plate arrangement; the papulae are single or in small groups and are usually confined to the abactinal surface but in *F. sadhensis* they also occur intermarginally and sometimes between the inferomarginal plates.

As noted by Clark (1967) *Ferdina* seems to occupy an isolated position within the family Ophiasteridae and this statement applies equally well to the other three genera of the

Ferdina group. However, despite their very different furrow armature, the nature of the abactinal skeleton, with larger abactinal plates superimposed on a reticulum of smaller plates in the two *Ferdina* species is similar to some species of *Nardoa* and *Gomphia* and a relationship may be inferred.

Key to the *Ferdina* group of genera.

- 1 Abactinal, marginal and actinal plates with a continuous covering of granules 2
- 1¹ Some marginal plates bare centrally 3
- 2 Abactinal plates irregular in size with larger convex plates superimposed on close fitting smaller ones, no regular longitudinal or transverse series of plates; supero marginals not in a regular series except at base and tip of arms, not easily distinguished from abactinal plates *Ferdina*
- 2¹ Abactinal plates irregular in size but longitudinal and transverse series often evident; superomarginals in a regular series, conspicuous *Paraferdina*
- 3 Abactinal plates irregular in size and arrangement but transverse and longitudinal rows are sometimes evident; superomarginals conspicuous when viewed from above; usually some abactinal plates as well as marginals bare centrally *Neoferdina*
- 3¹ Abactinal plates small, numerous, fairly regularly arranged, with a distinct carinal series; superomarginals not conspicuous when viewed from above; no bare abactinal plates *Sinoferdina*

Ferdina sadhensis sp. nov.

Figs 1–3

HOLOTYPE. BMNH 1990. 4.4.1 (dry)

TYPE LOCALITY. Sadh, near Wadi Haart, Sultanate of Oman, 17°04'N, 55°06'E, 6 m.

Coll. L. Barratt, 7 Oct. 1983 (831007, 2K7)

MATERIAL. In addition to the holotype, three paratypes (dry) and one other specimen (dry). Paratype 1, WAM 427–90, Hoones Bay east of Marbat, Dhofar, Sultanate of Oman, 5 m., coll. M. Morrison, 8 April 1988; paratype 2, USNM E41400, Urchin Pt., 16 km east of Marbat, Dhofar, Oman, 8–10 m., coll. M. Morrison, 5 Jan. 1990; paratype 3, University of Singapore, ZRC. 1990. 11806, same collection data as paratype 2; one specimen, A. C. Campbell collection, cat. no. 206030204, Urchin Pt., Oman, 13 m, rock, coll. M. Morrison, 5 April 1990.

ETYMOLOGY. The species name honours the villagers of Sadh, Sultanate of Oman, who contributed much to the work of one of us (A. C. C.).

DESCRIPTION OF HOLOTYPE. (Figs 1a-c, 2, 3a-c, g) The specimen has a small disc with five rays, constricted at the base then inflated to about 1/3 R from where they taper to a fairly acute tip. R = 53.8 to 56.2 mm (mean = 55.0 mm), r = 13.4 to 14.2 mm (mean = 13.8 mm), R/r = 3.99/1, br at base of arms is 15.8 mm, at the widest point is 17.0 mm and 10 mm from the arm tip it is 8.3 mm.

The abactinal skeleton consists of a mixture of large and small convex plates (fig. 3a). When the skeleton is cleaned some of the large plates are seen to lie on top of the small plates which form a close meshwork as described by A. M. Clark (1967) for *Ferdina flavescens*. There is little order in the arrangement of the plates but an indistinct carinal series of

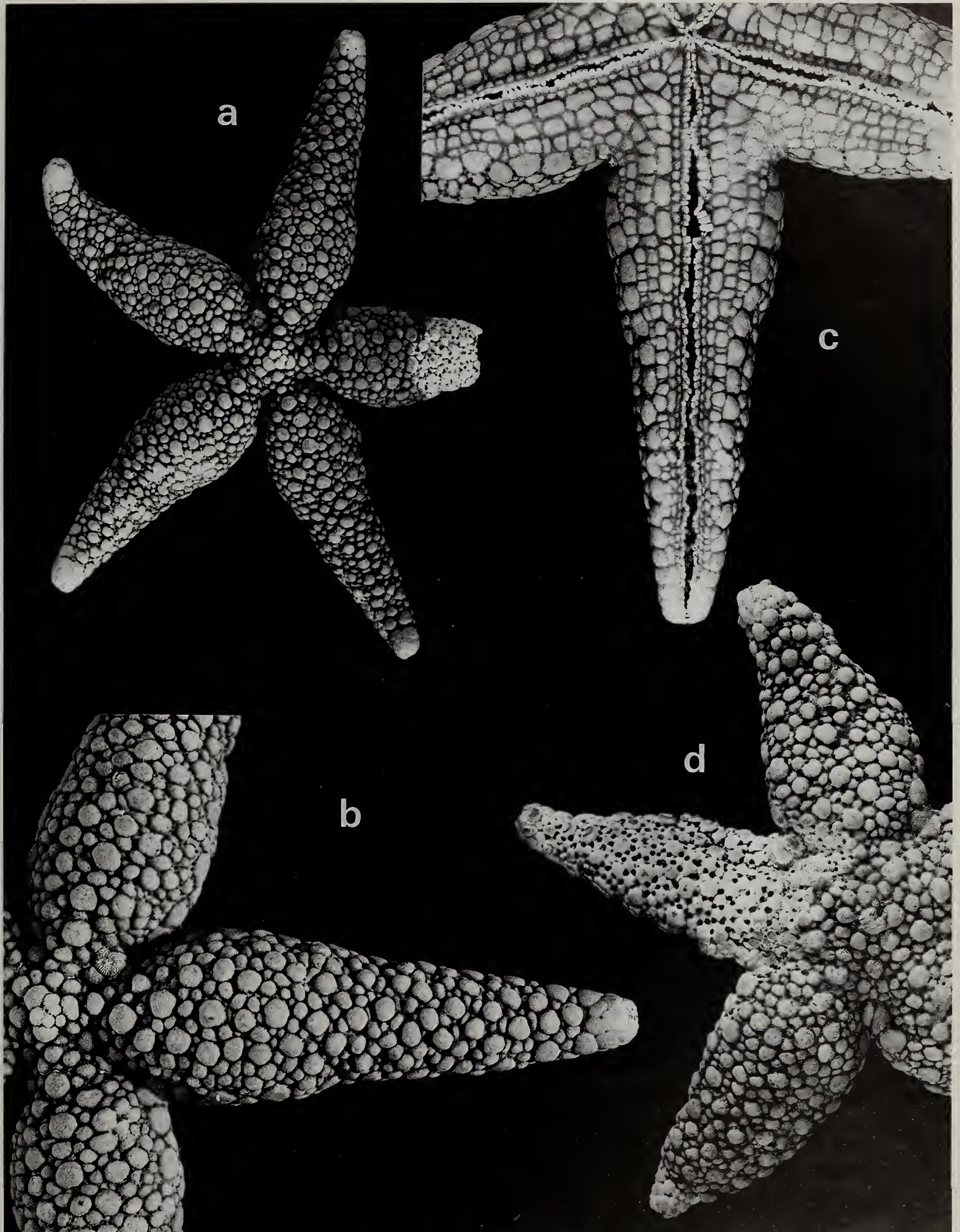


Fig. 1 *Ferdina sadhensis* n. sp., a, b, abactinal views of holotype (BMNH 1990.4.4.1, R/r = 55/13.8 mm); c, actinal view of holotype; d, abactinal view of paratype 1, arm on left denuded (WAM 427.90, R/r = 51.15/15.4 mm).

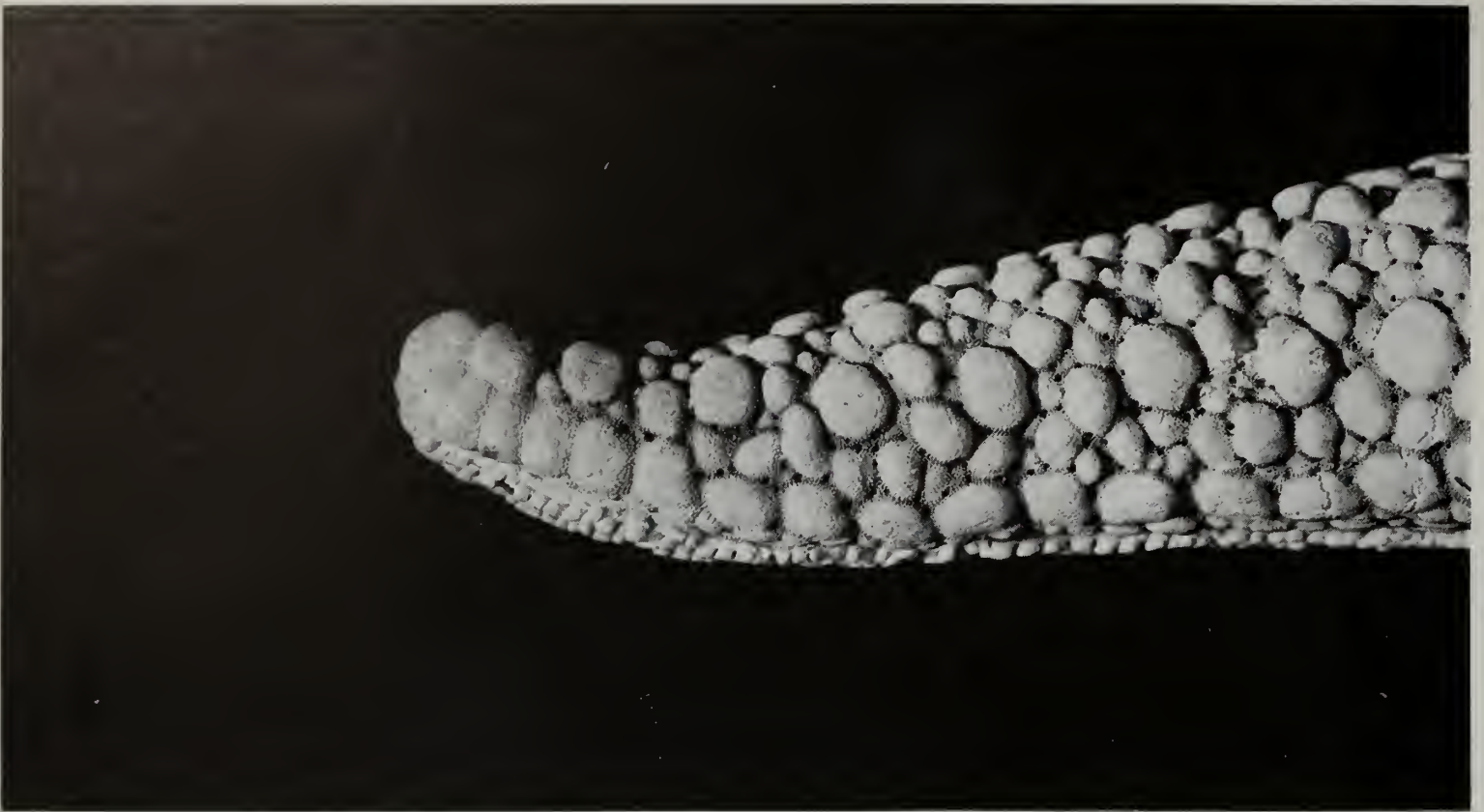


Fig. 2 *F. sadhensis* n. sp., lateral view of arm of holotype to show superomarginal, intermarginal and inferomarginal plates.

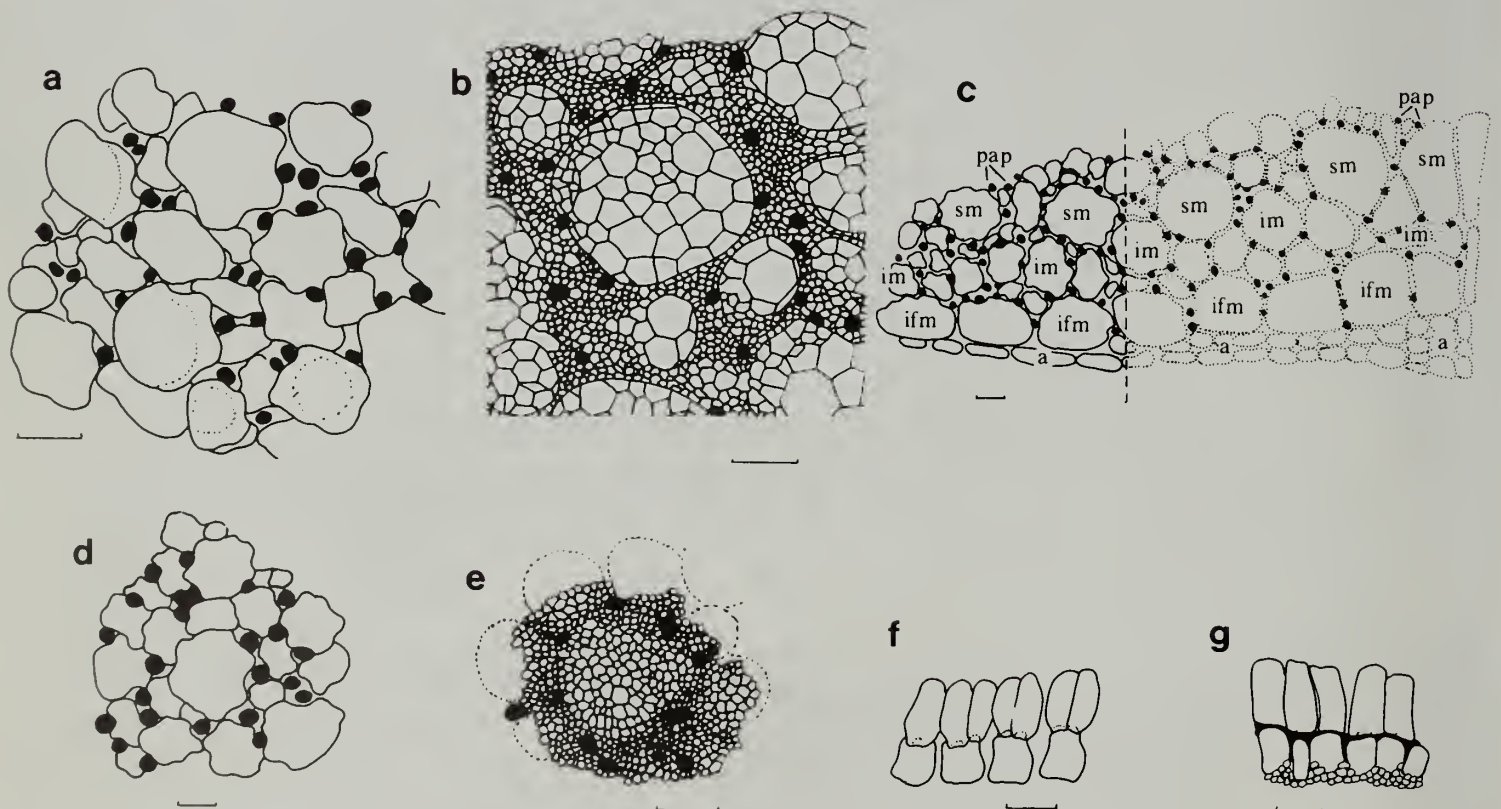


Fig. 3 *F. sadhensis* n. sp., a, abactinal plates of proximal part of arm, denuded (holotype); b, granulation of abactinal arm plates (holotype); c, lateral view of proximal half of arm, partly denuded (to left of dashed line), showing superomarginals (sm), intermarginals (im), inferomarginals (ifm) and some of the actinal plates (a), first marginals on right (holotype); d, abactinal plates of proximal part of arm, denuded (paratype 1); e, granulation of an abactinal arm plate (paratype 1); f, adambulacral plates and furrow spines, viewed from the furrow (paratype 1); g, oblique view across ambulacral furrow (black) showing outer, granule covered face of near side spines and inner surface of far side furrow spines (holotype). Papular pores (pap) shown black (figs a-e). (Scale bar = 1 mm.)

large plates (to 3.0 mm diam.) alternating with one or more smaller plates (*c.* 1.0 mm diam.) can be distinguished. Either side of the carinal series, and separated from it by an irregular series of smaller plates, is an indistinct row of large dorso-lateral plates, alternating irregularly with small plates. The remainder of the abactinal plates of the disc and arms are of mixed sizes mostly smaller than the carinal series; both large and small plates are notched for papulae (6–8 notches around the larger plates).

At the base of the ray there are 11 plates across the arm between the first superomarginals and 10 mm from the arm tip there are five plates (two large and three small) across the ray.

The madreporite is roughly four sided, situated nearer the margin than the centre of the disc. It measures 3.4×3.2 mm and is fairly irregularly and coarsely grooved. The anus is surrounded by about 15 wedge shaped to polygonal granules, crowded by five convex plates, then three larger convex plates.

The superomarginal plates match the inferomarginals in the arm angle where the first one or two pairs are adjacent (fig. 3c). Beyond this the inferomarginals continue as squarish plates (*c.* 3×3 mm), gradually decreasing in size towards the arm end (fig. 2); the inferomarginals number 23. The superomarginals diverge from the inferomarginals and are separated from them by intermarginal plates after the first two plates in the arm angle (figs 2, 3c). The superomarginal plates alternate irregularly with one or two small plates until near the arm end where they again lie in contact with the inferomarginals. On some rays the superomarginal series becomes so irregular that it is hard to distinguish. The larger superomarginals vary in shape, oval to polygonal, *c.* 3.5×3.0 mm, decreasing slightly in size distally; they number 25 including the small plates. The two marginal series are separated by 1–2 irregular series of small intermarginal plates (numbering up to 25), from the second superomarginal to the penultimate.

The terminal plate is bare apart from a few large granules and measures 1.4 to 1.8 mm in diameter.

The actinal plates are in 4 rows in the arm angle (fig. 1c). The row next to the adambulacrals extends to the 16–18th inferomarginal, the second row to the 15th (14–16th) inferomarginal, the third row to the 6 or 7th inferomarginal and the 4th row to the second or third inferomarginal. The innermost row of actinal plates starts from a single large square plate abutting the oral plates in three arm angles, in the other two this is unequally divided into two.

The adambulacral plates are smaller than the adjacent actinal plates. The furrow spines are equal or subequal, peg-like, truncate, flattened oval in section, usually two per plate (fig. 3g); the oral spines number 3–4 on each oral plate and are indistinguishable from the furrow series. The adambulacral armature is in a single series with no subambulacral spines.

The large, convex abactinal plates are covered by close-fitting, flat-topped polygonal granules from 1.1 mm diameter to 5/linear mm; on the smaller convex plates the granules are flat-topped or slightly convex, 1.5 to 6/linear mm. Between the plates the granules are very small, 8–9/linear mm (fig. 3b). The superomarginals and inferomarginals are fairly evenly granule covered with 5–6/mm, occasionally with a few larger granules. The actinal plates are covered by fairly even sized polygonal granules (6–7/mm) with smaller granules between the plates (8–9/mm). The actinal granulation extends partway up the outer side of the furrow spines.

There are no crystal bodies on any of the plates. Papulae occur singly or in small groups of 3–5 abactinally; they also occur intermarginally and between some of the inferomarginal plates and at the lower corners of some inferomarginals but there are no pores among the actinal plates.

Colour (dry). Granules on the raised plates are buff, between the plates deep claret red; actinally, granules on the plates are buff with those between the plates deep magenta.

PARATYPE 1. WAM 427–90, (figs 1d, 3d-f) has R of 50.8 to 51.5 mm (mean 51.15), $r = 15.4$ mm, $R/r = 3.3/1$; br at arm base = 17.0 mm, at its widest point 18.5 mm and 10 mm from the arm tip it is 9.6 mm.

The general appearance is very similar to that of the holotype, with the largest abactinal plates measuring 3.0 mm diameter (fig. 3d). However the granules on the large plates are more uniform in size and much smaller, 3–5/linear mm (fig. 3e). There are 23 superomarginal plates and 24 inferomarginals. The actinal plates are in three rows with only 1 or 2 plates of a 4th row. The innermost row extends to 13–16th inferomarginal, the second row to the 10–12th and the third row to the 3–5th inferomarginal.

The furrow spines are as described above except that in the paratype the tips are rounded, not truncated (fig. 3f). There are 3–4 oral spines. Papulae occur singly and there are none between or below the inferomarginals.

PARATYPE 2. USNM E41400, has R of 46 to 50 mm (mean 48), plus two shorter regenerating arms, $r = 12$ mm, $R/r = 4.0/1$; br at arm base = 12.5 mm, at its widest point 13 mm and 10 mm from the arm tip it is 7.5 mm.

The general appearance is very similar to that of the holotype and paratype 1 except that the arms are more slender and hardly constricted at the base.

There are eight abactinal plates across the arm base between the superomarginals and five across the arm 10 mm from the tip. The madreporite is triangular, flanked by three rectangular to semicircular convex plates with their longest sides abutting the madreporite. The superomarginal plates are very irregular in size, shape and position except for a prominent first pair and 3–4 regular plates near the arm end; intermarginal plates are found in some arm angles, in others they start after the first or second superomarginal, on some arms they extend to about three quarters of the arm length. The actinal plates are in 3–4 rows at the arm base.

The large convex abactinal plates are covered by close packed, polygonal, slightly convex granules of mixed sizes, 2–6/mm with small interstitial granules numbering 8–9/mm; the actinal plates have 5–6 granules/mm with interstitial granules numbering 7–8/mm. Papulae occur singly with about eight around large abactinal plates, two intermarginal series and none below the inferomarginals.

The colour is as described for the holotype but slightly faded.

PARATYPE 3. University of Singapore, ZRC. 1990. 11806, has R of 47 to 56 mm (mean 53.6), plus one regenerating arm, $r = 11.5$ mm, $R/r = 4.6/1$; br at arm base = 14 mm, widening to 16–17 mm at one third R then tapering to br of 7.5 mm at 10 mm from the arm end. One arm, regenerating from the base, originates under the disc and has parallel sides with br of 8.3 mm.

There are eight abactinal plates across the arm base, reducing to five at 10 mm from the arm end. The madreporite

is triangular, flanked by five plates. The superomarginal plates are very irregular except at the base and end of the arms; intermarginal plates commence after the first or second superomarginal.

The large convex abactinal plates have close packed, polygonal granules, 3–6/mm, the actinal plates have 6 granules/mm with interstitial granules numbering 8/mm. Papulae occur singly or in pairs abactinally and intermarginally with a few between the inferomarginals, none below.

The remaining specimen (Campbell collection) has R/r of 48/11.5 mm = 4.2/1, br = 12.5 mm at base and 7.0 mm at 10 mm from arm tip, the arms are not inflated at one third R or constricted at base.

This specimen has more regular superomarginal plates on some arms where in places large and small plates alternate; intermarginal plates are fewer than in the other specimens. The granulation approaches that of the holotype with granules of very mixed sizes, 1 to 5/mm on some convex plates, the interstitial granules are very small, 9/mm; on the actinal plates there are 5–6 granules/mm with interstitial granules 9/mm.

The colour is as described for the holotype except that the arm tips are cream and the interstitial granules on a regenerating arm are dark brown.

VARIATION. The holotype is the largest specimen with R/r of 55.0/13.8 mm (3.99/1), the smallest has R/r of 48/11.5 mm (4.2/1), R/r varies from 3.3/1 to 4.6/1; br at the arm base varies from 12.5 to 17 mm, at the widest point from 13 to 18.5 mm and 10 mm from the arm end from 7.0 to 9.6 mm.

All the specimens have a mixture of large and small convex abactinal plates with flat to slightly convex polygonal granules of very mixed sizes. The largest granules are 1.1 mm in diameter on the holotype but another specimen has granules 1 mm in diameter, they range from <1 to 6/mm with interstitial granules fairly uniform at 8–9/mm.

Superomarginal plates are generally very irregular except at the arm base and end but one specimen has a distinct superomarginal series on some arms with a tendency for large and small plates to alternate. This specimen has few intermarginal plates but they are well developed in the others.

The colour pattern is very uniform and more or less retained in the dry specimens which were compared with an underwater colour photograph taken at Urchin Point at 18 m depth. This shows yellowish buff convex plates with wine red interstitial granules except on a regenerating arm where they are dark brown, the arm tips are cream.

HABITAT. Sublittoral, collected between 5 and 13 m and photographed at 18 m. It appears to live on metamorphic rock encrusted with red coralline algae and supporting brown turf algae. Hard corals, principally *Acropora* spp., occur at all the sites but there is no evidence that *F. sadhensis* is coral associated. Forests of the brown alga *Sargassopsis* sp. develop thick growths, between one and two metres tall, in the zone populated by *F. sadhensis* following the South-West Monsoon.

DISTRIBUTION. At present known only from the south coast of Oman.

REMARKS. On first examination the present specimens were thought to represent a new genus but the difference from *Ferdina*, as diagnosed by Clark (1967), were found to be insufficient to justify excluding them from the genus *Ferdina*.

F. sadhensis is thus the second species of the genus *Ferdina*. Rather than erect a new genus the generic diagnosis (Clark 1967) is modified slightly to take account of the new species.

F. sadhensis differs from *F. flavescens* in having swollen rays sometimes constricted at the base and tapering to a narrow tip; more convex abactinal plates; a greater difference between the size of granules on the abactinal plates and those between them and, in the holotype at least, distinct superomarginals with intermarginals between supero- and inferomarginals.

Perrier (1875), de Loriol (1885) and Clark (1967) note that the skeletal plates of *F. flavescens* are concealed by a uniform coat of fine granules, however in Livingstone's enlarged figure of the holotype (1931, pl. 22, fig. 3) there is a noticeable difference in the size of granules on the convex plates compared to those between them, but less so than in *F. sadhensis*.

The actinal surface of the new species closely resembles that of *F. flavescens* and *Neoferdina* spp in having the granule covered skin extending part way up the outer side of the single row of furrow spines. As in *Neoferdina* the actinal plates are outlined in a contrasting colour.

The genus *Ferdina* is apparently confined to the Indian Ocean, west of 60°E, between 20°N and 20°S, however *N. flavescens* has only been found in Mauritius and *F. sadhensis* only in Oman.

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